

# Labs21: Improving the Performance of U.S. Laboratories

Dale Sartor  
Lawrence Berkeley National Laboratory

## Laboratory Buildings

“Labs embody the spirit, culture, and economy of our age... what the cathedral was to the 14th century and the office building was to the 20th century, the laboratory is to the 21st century.”

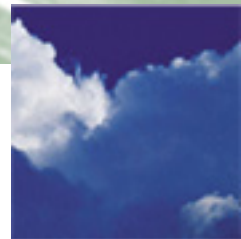
Don Prowler



College of Engineering, Rowan University

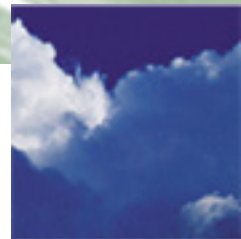
## Energy Use at Laboratories

- Laboratories are energy intensive.
  - On a square foot basis, labs often consume four to six times as much energy as a typical office building.
- Most existing labs can reduce energy use by 30%-50% with existing technology.
- Laboratories are experiencing significant growth.
- Energy cost savings possible from U.S. labs may be as much as \$1 billion to \$2 billion annually.



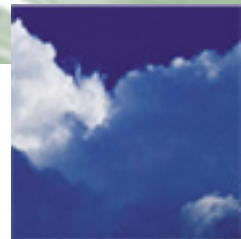
## What is Labs21?

- A joint EPA/DOE partnership program to improve the environmental performance of U.S. laboratories.
- Encourages the design, construction, and operation of sustainable, high-performance facilities that will:
  - Minimize overall environmental impacts.
  - Protect occupant safety.
  - Optimize whole building efficiency on a lifecycle basis.



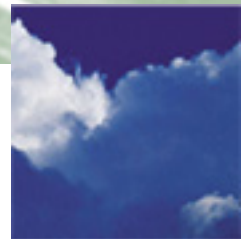
## Labs21 Goals

- Improve energy efficiency and performance of new and existing laboratories through targeted **technical assistance**
- Increase **capacity-building** in the laboratory sector through training and peer-to-peer information exchange



## **Labs21: A Vibrant Program**

- Growing network of more than 3,500 laboratory designers, engineers, facility/energy managers, health and safety personnel, and others.
- Trained thousands of professionals.
- Attracts over 500 attendees to the annual international conference.
- Actively working with dozens of Partners and Supporters.
- Partnering with Centers of Excellence to expand technical capacity and program reach.



## Labs21 Program Components

### 1. Partnership Program

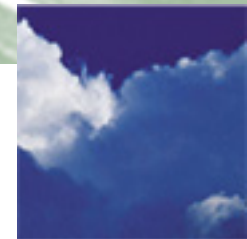
- Draws together lab owners and designers committed to implementing high performance lab design.

### 2. Training Program

- Includes annual technical conference, training workshops, and other peer-to-peer opportunities.

### 3. Best Practices and Tool Kit

- An Internet-accessible compendium of case studies and other information on lab design and operation, building on the *Design Guide for Energy Efficient Research Laboratories* developed by Lawrence Berkeley National Laboratory, and more...





## Component #1: Partnership Program

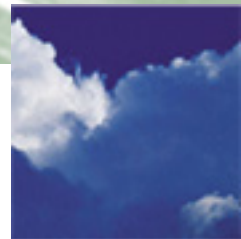
- EPA and DOE are partnering with interested lab owners.
- Working with Labs21, each partner will:
  - Set voluntary goals.
  - Assess the opportunities for improvements.
  - Measure and report progress.





## Benefits of Partnership

- Technical Assistance
  - Participation in sustainable design charrettes
  - Advice on specific technical issues (e.g. heat recovery, fume hoods)
  - Help using Labs21 toolkit
- Networking
  - Opportunities to network and share results with peers
- National recognition
  - Thru Labs21 events, awards, and promotional materials



## Partnership Requirements

- Adopt the Labs21 principles.
- Commit to a specific project (new or retrofit).
- Develop a method to measure and evaluate success.
- Grant Labs21 permission to publicize partnership activities.
- Participate in the annual Labs21 conference.

# Labs21 Partners

## *Private Sector Partners*

- Bristol-Myers Squibb
- Carnegie Mellon University
- Duke University
- Genzyme
- Harvard University
- New York City Public School Authority
- Northern Arizona University
- Pfizer
- Raytheon
- Sonoma State University
- University of California – Merced
- University of Hawaii
- University of North Carolina – Asheville
- Wyeth-Ayerst Pharmaceuticals



## Labs21 Federal Partners

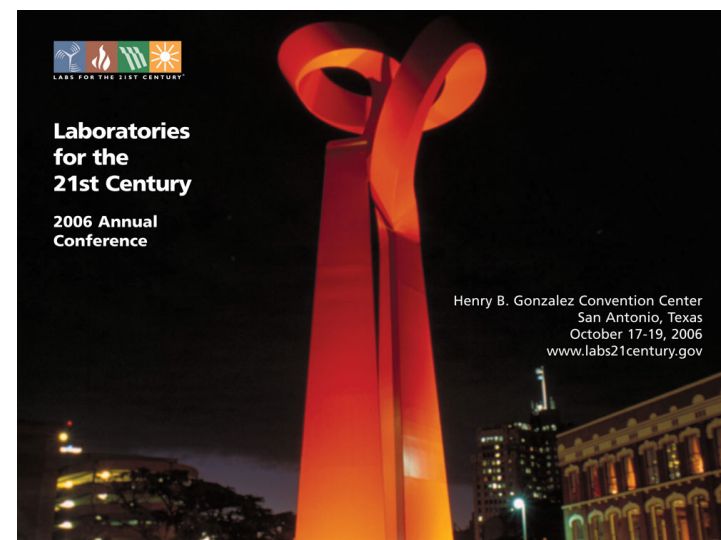
- Lawrence Berkeley National Laboratory
- National Aeronautics & Space Administration
- National Oceanic & Atmospheric Administration
- National Renewable Energy Laboratory
- National Science Foundation
- Sandia National Laboratories
- U.S. Department of Agriculture
- U.S. Environmental Protection Agency





## Component #2: Training

- A comprehensive education and training program that targets:
  - Design professionals.
  - Laboratory O&M management.
  - Energy managers.
- Annual conference
- One day introductory course
- Advanced course modules
  - LEED for Labs
  - Lab ventilation
- Phone forums on specific topics
- Video with case studies
- Student design competition
- Partnership with UC/CSU/IOU's



*October 17-19, 2006*

*Henry B. Gonzalez Convention Center  
San Antonio, TX*

## **Labs21 Training and TA is focused on unique challenges and opportunities in Labs**

- VAV fumehoods
- Low flow fumehoods
- Energy recovery
- Minimizing reheat
- Low pressure drop design
- Multi-stack exhaust
- Fumehood and laboratory Commissioning
- Indoor air flow modeling
- Optimizing air change rates
- Effluent dispersion
- Plug loads and rightsizing
- Lab equipment efficiency
- Daylighting in labs
- Effective electrical lighting design
- Flexible servicing configurations
- Green materials for labs



## Component #3: Toolkit

- *For an overview*
  - Intro to Low-Energy Design
  - Video
- *Core information resources*
  - Design Guide
  - Case Studies
  - Energy Benchmarking
  - Best Practice Guides
- *Design process tools*
  - Env. Performance Criteria
  - Design Intent Tool
  - Labs21 Process Manual

[www.labs21century.gov/toolkit](http://www.labs21century.gov/toolkit)

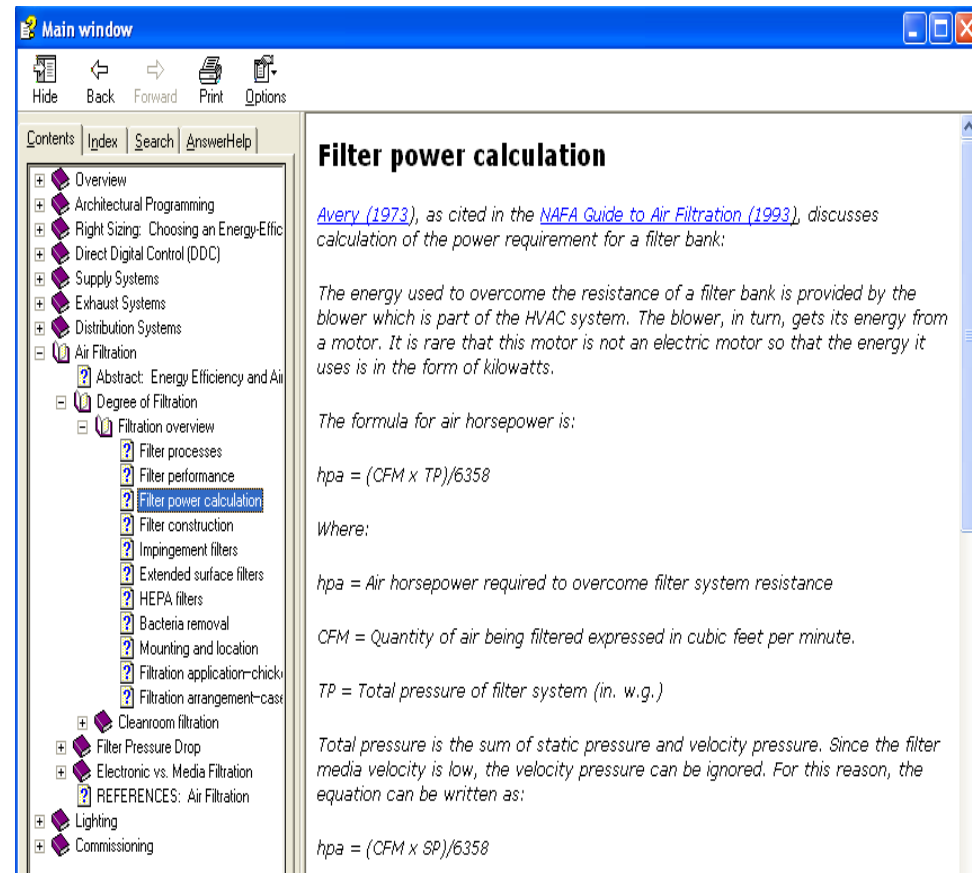
The collage displays various components of the Labs21 Toolkit website. Key elements include:

- Design Process Checklist:** A sidebar listing project stages from Pre-Design to Construction, with a main window for selecting energy systems.
- Overview of manifold exhaust systems:** A text-based overview with a diagram illustrating the concept of manifold exhaust in laboratory buildings.
- Case Studies:** A section titled 'LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES' featuring 'THE LOUIS STOKES LABORATORY BUILDING 50, NATIONAL INSTITUTE OF HEALTH, BETHESDA, MARYLAND'.
- Benchmarking:** A page titled 'benchmarking' showing a bar chart of 'Total Building BTU/sf-yr (site)' for various facilities, with a red marker indicating estimated values.
- Graphing:** A page titled 'Graphing' showing a similar bar chart for 'Total Building BTU/sf-yr (site)'.

## Core information resources

### Lab Design Guide

- A detailed reference on high-performance, low-energy lab design and operation
- 4-level hierarchy – from general to specific
- Searchable
- Available on web and CD



The screenshot shows a software window titled 'Main window' with a menu bar (Hide, Back, Forward, Print, Options) and a toolbar. The left pane displays a hierarchical tree of topics. The right pane shows the 'Filter power calculation' section, which includes a paragraph about Avery (1973), a formula for air horsepower, and definitions for variables.

**Filter power calculation**

*Avery (1973), as cited in the [NAFA Guide to Air Filtration \(1993\)](#), discusses calculation of the power requirement for a filter bank:*

*The energy used to overcome the resistance of a filter bank is provided by the blower which is part of the HVAC system. The blower, in turn, gets its energy from a motor. It is rare that this motor is not an electric motor so that the energy it uses is in the form of kilowatts.*

*The formula for air horsepower is:*

$$hpa = (CFM \times TP) / 6358$$

*Where:*

*hpa = Air horsepower required to overcome filter system resistance*

*CFM = Quantity of air being filtered expressed in cubic feet per minute.*

*TP = Total pressure of filter system (in. w.g.)*

*Total pressure is the sum of static pressure and velocity pressure. Since the filter media velocity is low, the velocity pressure can be ignored. For this reason, the equation can be written as:*

$$hpa = (CFM \times SP) / 6358$$

## Core information resources

### Best Practice Guides

- Describes how to implement a strategy, with implementation examples
- Completed guides:
  - Combined Heat and Power
  - Daylighting in Laboratories
  - Energy Recovery
  - Low-pressure drop design
  - Modeling Exhaust Dispersion
  - Water Efficiency
  - Minimizing Reheat
  - Right-sizing
- Several in development
  - Labs21 seeking contributing authors



#### LABORATORIES FOR THE 21ST CENTURY: BEST PRACTICES



Johns Hopkins School of Medicine/PHS/CI200

The Bunting Blaustein Cancer Research Building in Baltimore, Maryland, is one of several buildings at Johns Hopkins that use enthalpy wheels for energy recovery.

#### ENERGY RECOVERY FOR VENTILATION AIR IN LABORATORIES

##### Introduction

Energy recovery can substantially reduce the mechanical heating and cooling requirements associated with conditioning ventilation air in most laboratories. Laboratories typically require 100% outside air at high ventilation rates—between 6 and 15 air changes per hour—primarily for safety reasons. The heating and cooling energy needed to condition this air, as well as the fan energy needed to move it, is 5 to 10 times greater than the amount of energy used in most offices for those purposes. Heating and cooling systems can be downsized when energy recovery is used, because energy recovery systems reduce peak heating and cooling requirements.




U.S. Department of Energy  
Energy Efficiency and Renewable Energy  
Federal Energy Management Program



## Case Studies

- Bren Hall, UCSB
- Fred Hutchinson Cancer Research Center
- Georgia Public Health Laboratory
- Haverford College Natural Science Center
- National Institutes of Health Building 50
- Sandia National Laboratories PETL
- Nidus Center
- Pharmacia Building Q
- U.S. EPA National Vehicle and Fuel Emissions Lab
- Whitehead Biomedical Research Center, Emory University

*All case studies have whole-building and system level energy use data*



### LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES

**Case Study Index**

**Laboratory Type**

- ✓ Wet lab
- Dry lab
- Clean room

**Construction Type**

- ✓ New
- Retrofit

**Type of Operation**

- Research/development
- Manufacturing
- Teaching
- ✓ Chemistry
- ✓ Biology
- Electronics

**Service Option**

- Suspended ceiling
- Utility corridor
- ✓ Interstitial space

**Featured Technologies**


- ✓ Fume hoods
- ✓ Controls
- ✓ Mechanical systems
- ✓ Electrical loads
- Water conservation
- Renewables
- Sustainable design/planning
- On-site generation

**Other Topics**

- Diversity factor
- Carbon trading
- Selling concepts to stakeholders
- Design process

**LEED Rating**


- Platinum
- Silver
- Bronze




### THE LOUIS STOKES LABORATORIES, BUILDING 50, NATIONAL INSTITUTES OF HEALTH, BETHESDA, MARYLAND

**Introduction**

The Louis Stokes Laboratories, Building 50 at the National Institutes of Health (NIH) in Bethesda, Maryland, reflects a strong commitment to the energy-efficiency goals of the Laboratories for the 21st Century program, a joint endeavor of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). In an aggressive approach to energy efficiency, the building incorporates the use of daylighting, variable-air-volume (VAV) control of the ventilation air supply and exhaust, and energy recovery from the exhaust air stream. Using a modified interstitial space as a core design feature, the NIH building is flexible enough to accommodate change and ensure that it will be used both now and in the future. The study is geared toward architects and engineers who are familiar with laboratory buildings. This program is part of a series that encourages the design, construction and operation of safe, sustainable, high-performance laboratories.



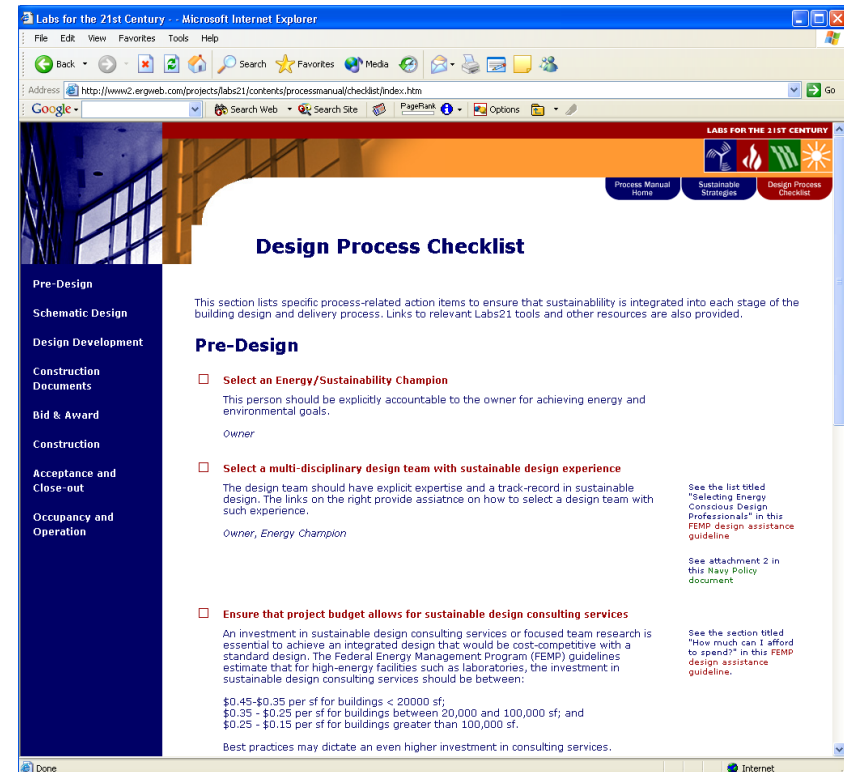
United States  
Environmental Protection  
Agency



United States  
Department of  
Energy

# Process Manual

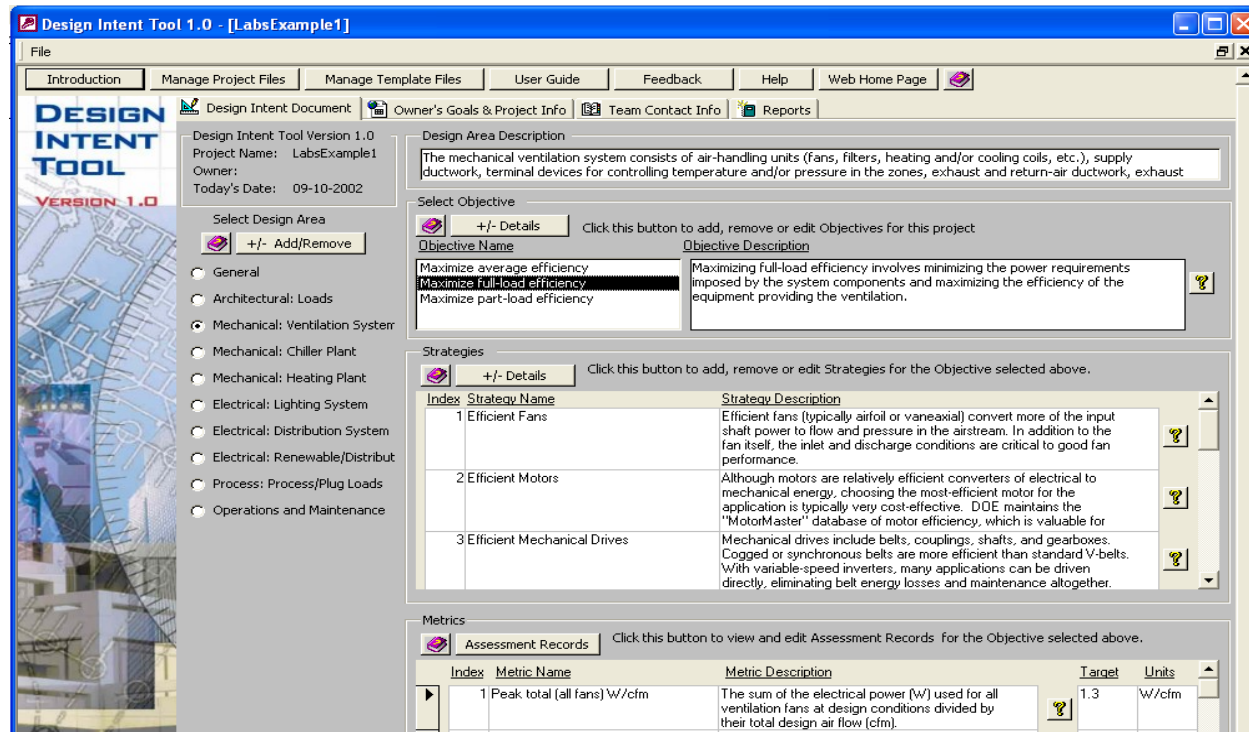
- Provides design process guidance
- Action items for each stage of design process
  - Links to appropriate tools and resources
- Checklist of sustainable design strategies
  - Portal to core information resources
  - Useful for design charrettes





# Design Intent Tool

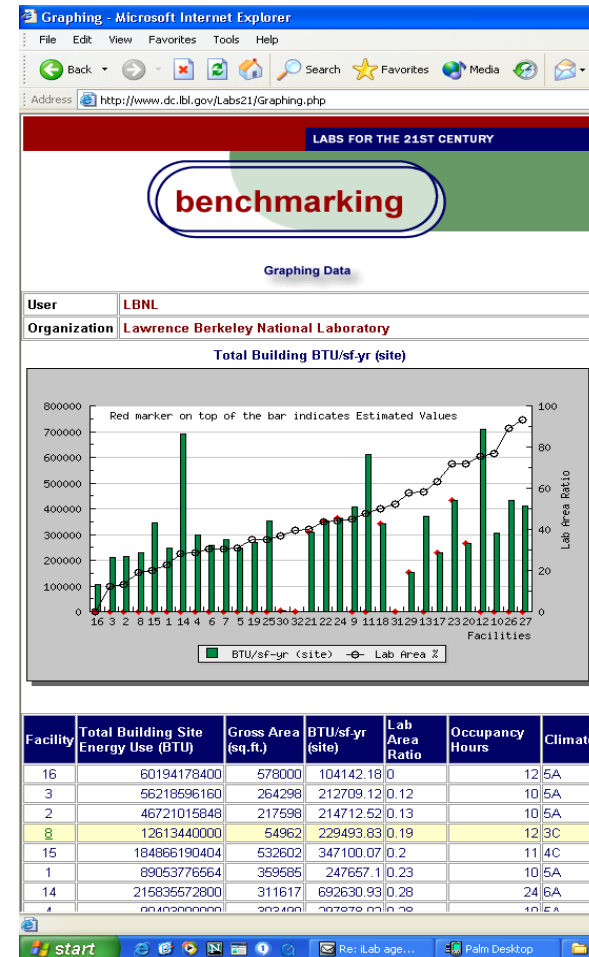
- A database tool to document intended strategies and metrics during design





# Energy Benchmarking Tool

- National database of lab energy use data
- Web-based input and analysis
- About 70 facilities
- Building level data (e.g. Site BTU/sf)
- System level data (e.g. W/cfm)
- Why benchmark?
  - See where you stand
  - Set targets



## Benchmarking Metrics

| System       | Energy Consumption   | Energy Demand                                       |
|--------------|--|---|
| Ventilation  | kWh/sf-yr  | Peak W/cfm<br>Peak cfm/sf (lab)<br>Avg cfm/peak cfm |
| Cooling      | kWh/sf-yr  | Peak W/sf<br>Peak sf/ton<br>kW/ton                  |
| Lighting     | kWh/sf-yr  | Peak W/sf   |
| Process/Plug | kWh/sf-yr  | Peak W/sf   |
| Heating      | BTU/sf-yr  | Peak W/sf   |
| Aggregate    | kWh/sf-yr (total elec)<br>BTU/sf-yr (site)<br>BTU/sf-yr (source)<br>Utility \$/sf-yr | Peak W/sf<br>Effectiveness (Ideal/Actual)           |

# Labs21 Benchmarking Tool – Data Input

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

**LABS FOR THE 21ST CENTURY**

**benchmarking**

step one of four - login  
 step two of four - enter facility name and year of data  
**step three of four - enter data for the facility**  
 step four of four - review / edit entered data

\* Indicates Required Input

**Data / Facility Information**

|                 |                                       |
|-----------------|---------------------------------------|
| User            | LBNL                                  |
| Organization    | Lawrence Berkeley National Laboratory |
| Facility chosen | Bldg2-AdvancedMaterialLab             |
| Year chosen     | 2001                                  |

**General Facility**

|                       |                      |
|-----------------------|----------------------|
| Street Address*       | One Cyclotron Road   |
| Location*             | Berkeley, CA         |
| Zip Code (5 digit)*   | 94720                |
| Lab Use*              | Research/Development |
| Lab Type*             | Combination/Others   |
| Lab Category*         | Combination/Others   |
| Number of Building(s) | 1                    |
| Gross Area (sq. ft.)* | 85761                |

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

**Energy Use**

|  | Measured | Estimated |
|--|----------|-----------|
| Annual Energy Utility Cost (\$)*                       | 231000   |           |
| Annual Heating Energy (therms)*                        | 124800   |           |
| Does facility use CHP (Cogen) system?                  | No       |           |
| <b>Annual Electric Use (kWh)</b>                       |          |           |
| Total*   | 2526000  |           |
| Ventilation  | 1010000  |           |
| Cooling Plant (including campus chilled water, if any) | 298000   |           |
| Lighting   | 460000   |           |
| Process/plug   | 1150000  |           |
| <b>Peak Demand (kW)</b>                                |          |           |
| Total*   | 478      |           |
| Ventilation  | 0        |           |
| Cooling Plant (including campus chilled water, if any) | 0        |           |
| Lighting   | 0        |           |
| Process/plug   | 0        |           |

**System**

|   | Measured | Estimated |
|---|----------|-----------|
| Peak Cooling Load (Tons)  | 0        |           |
| Average Cooling Load (Tons)<br>(Total annual cooling ton-hours divided by 8760) | 0        |           |
| Cooling Plant Capacity (Tons)   | 500      |           |
| Peak CFM<br>(Sum of exhaust, supply, and recirculating fans)                    | 0        |           |
| Average CFM<br>(Sum of exhaust, supply, and recirculating fans)                 | 0        |           |

# Labs21 Benchmarking Tool – Analysis

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://www.dcl.gov/Labs21/CompareData.php?UserID=2

**LABS FOR THE 21ST CENTURY**

**benchmarking**

Choose Metrics and Filtering Criteria

[More Information](#)

User **LBNL**

Organization **Lawrence Berkeley National Laboratory**

Please specify the metric criteria -

System Total Building

Energy / Efficiency Metric BTU/sf-yr (site)

Please specify the filtering criteria -

1. Lab Area / Gross Area ratio

is greater than or equal to 0.00 and is less than or equal to 0.99

2. Occupancy

☐ Standard (≤14 hours)

☐ High (>14 hours)

☒ Both (all data)

3. Climate [Climate Code, Climate Type, Representative City]

(To view the map of climatic distribution)

☒ 1A, Very Hot - Humid (Miami, FL)

☒ 2B, Hot - Dry (Phoenix, AZ)

☒ 3B, Warm - Dry (El Paso, TX)

☒ 4A, Mixed - Humid (Baltimore, MD)

☒ 4C, Mixed - Marine (Salem, OR)

☒ 5B, Cool - Dry (Bosie, ID)

☒ 6B, Cold - Dry (Helena, MT)

☒ 8, Subarctic (Fairbanks, AK)

☒ 2A, Hot - Humid (Houston, TX)

☒ 3A, Warm - Humid (Memphis, TN)

☒ 3C, Warm - Marine (San Francisco, CA)

☒ 4B, Mixed - Dry (Albuquerque, NM)

☒ 5A, Cool - Humid (Chicago, IL)

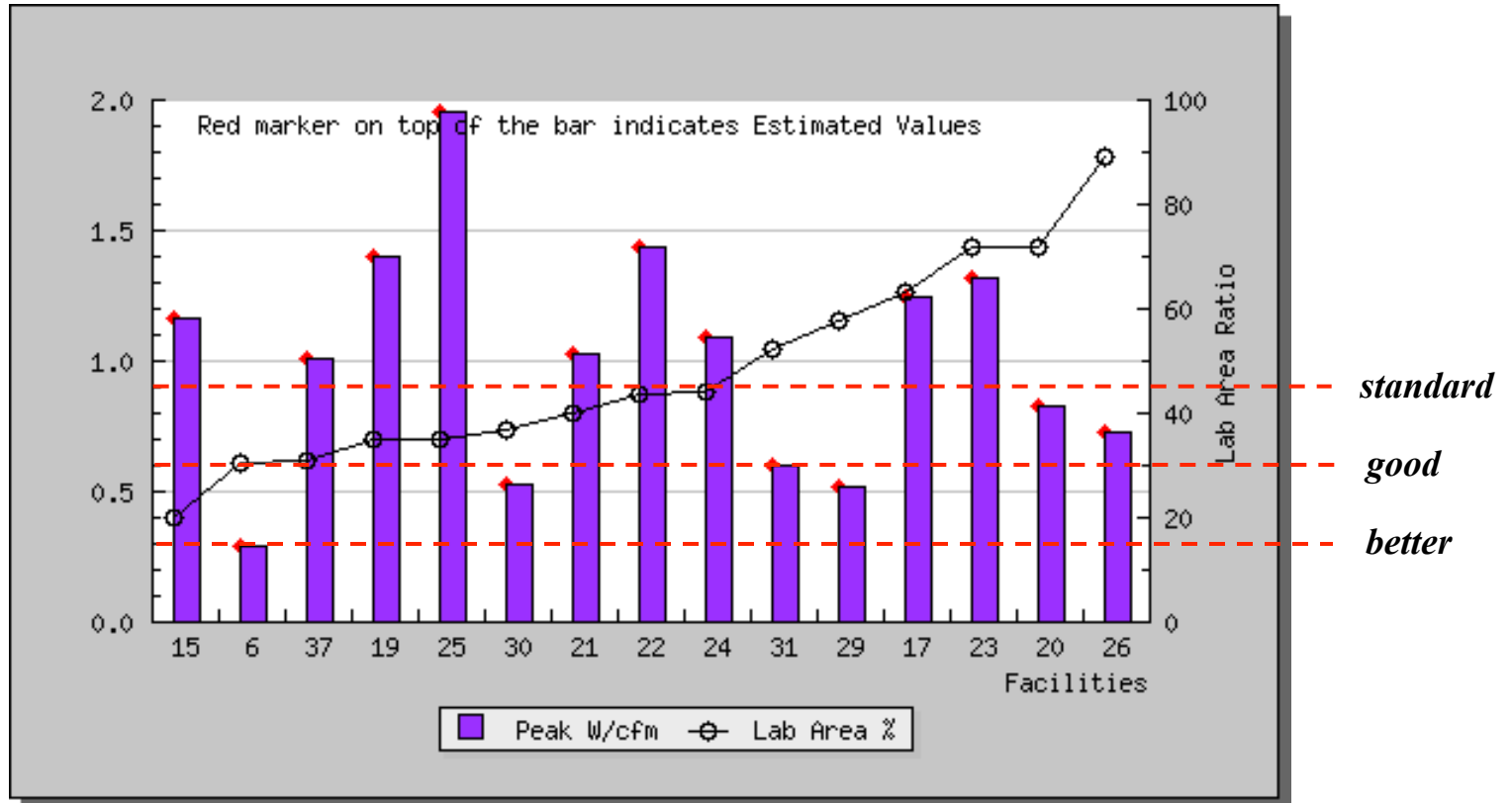
☒ 6A, Cold - Humid (Burlington, VT)

☒ 7, Very Cold (Duluth, MN)

Reset Values Continue...



## Labs21 Benchmarking Tool – Vent. W/cfm



Standard, good, better benchmarks as defined in  
 “How-low Can You go: Low-Pressure Drop Laboratory Design”  
 by Dale Sartor and John Weale

## Environmental Performance Criteria (EPC)

- A rating system for evaluating laboratory design.
  - Builds on the LEED™ rating system
- Adds credits and prerequisites pertaining to labs
  - Health & Safety
  - Fumehood energy use
  - Plug loads
- Leveraged volunteer efforts
  - > 40 architects, engineers, facility managers, and health and safety personnel.
  - > 200 person hours contributed
- USGBC developing LEED for Labs based on EPC

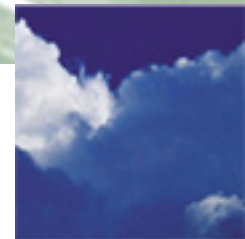


## EPC & LEED

|     |   |    | Indicates additions/modifications to LEED  |           |
|-----|---|----|--|-----------|
| Yes | ? | No |  |           |
| 0   | 0 | 0  | <b>Sustainable Sites</b>   | <b>16</b> |
| Y   |   |    | Prereq 1 <b>Erosion &amp; Sedimentation Control</b>                                | Required  |
|     |   |    | Credit 1 <b>Site Selection</b>   | 1         |
|     |   |    | Credit 2 <b>Urban Redevelopment</b>  | 1         |
|     |   |    | Credit 3 <b>Brownfield Redevelopment</b>   | 1         |
|     |   |    | Credit 4.1 <b>Alternative Transportation, Public Transportation Access</b>         | 1         |
|     |   |    | Credit 4.2 <b>Alternative Transportation, Bicycle Storage &amp; Changing Rooms</b> | 1         |
|     |   |    | Credit 4.3 <b>Alternative Transportation, Alternative Fuel Refueling Stations</b>  | 1         |
|     |   |    | Credit 4.4 <b>Alternative Transportation, Parking Capacity</b>                     | 1         |
|     |   |    | Credit 5.1 <b>Reduced Site Disturbance, Protect or Restore Open Space</b>          | 1         |
|     |   |    | Credit 5.2 <b>Reduced Site Disturbance, Development Footprint</b>                  | 1         |
|     |   |    | Credit 6.1 <b>Stormwater Management, Rate or Quantity</b>                          | 1         |
|     |   |    | Credit 6.2 <b>Stormwater Management, Treatment</b>                                 | 1         |
|     |   |    | Credit 7.1 <b>Landscape &amp; Exterior Design to Reduce Heat Islands, Non-Roof</b> | 1         |
|     |   |    | Credit 7.2 <b>Landscape &amp; Exterior Design to Reduce Heat Islands, Roof</b>     | 1         |
|     |   |    | Credit 8 <b>Light Pollution Reduction</b>  | 1         |
|     |   |    | Credit 9.1 <b>Safety and Risk Management, Air Effluent</b>                         | 1         |
|     |   |    | Credit 9.2 <b>Safety and Risk Management, Water Effluent</b>                       | 1         |
| Yes | ? | No |  |           |
| 0   | 0 | 0  | <b>Water Efficiency</b>  | <b>7</b>  |
| Y   |   |    | Prereq 1 <b>Laboratory Equipment Water Use</b>                                     | Required  |
|     |   |    | Credit 1.1 <b>Water Efficient Landscaping, Reduce by 50%</b>                       | 1         |
|     |   |    | Credit 1.2 <b>Water Efficient Landscaping, No Potable Use or No Irrigation</b>     | 1         |
|     |   |    | Credit 2 <b>Innovative Wastewater Technologies</b>                                 | 1         |

## How to Become Involved

- Contact:  
Dan Amon  
U.S. EPA  
(202) 564-7509  
Amon.Dan@epamail.epa.gov
- Visit: [www.labs21century.gov](http://www.labs21century.gov)
- E-mail the Labs21 Network: [labs21@erg.com](mailto:labs21@erg.com)



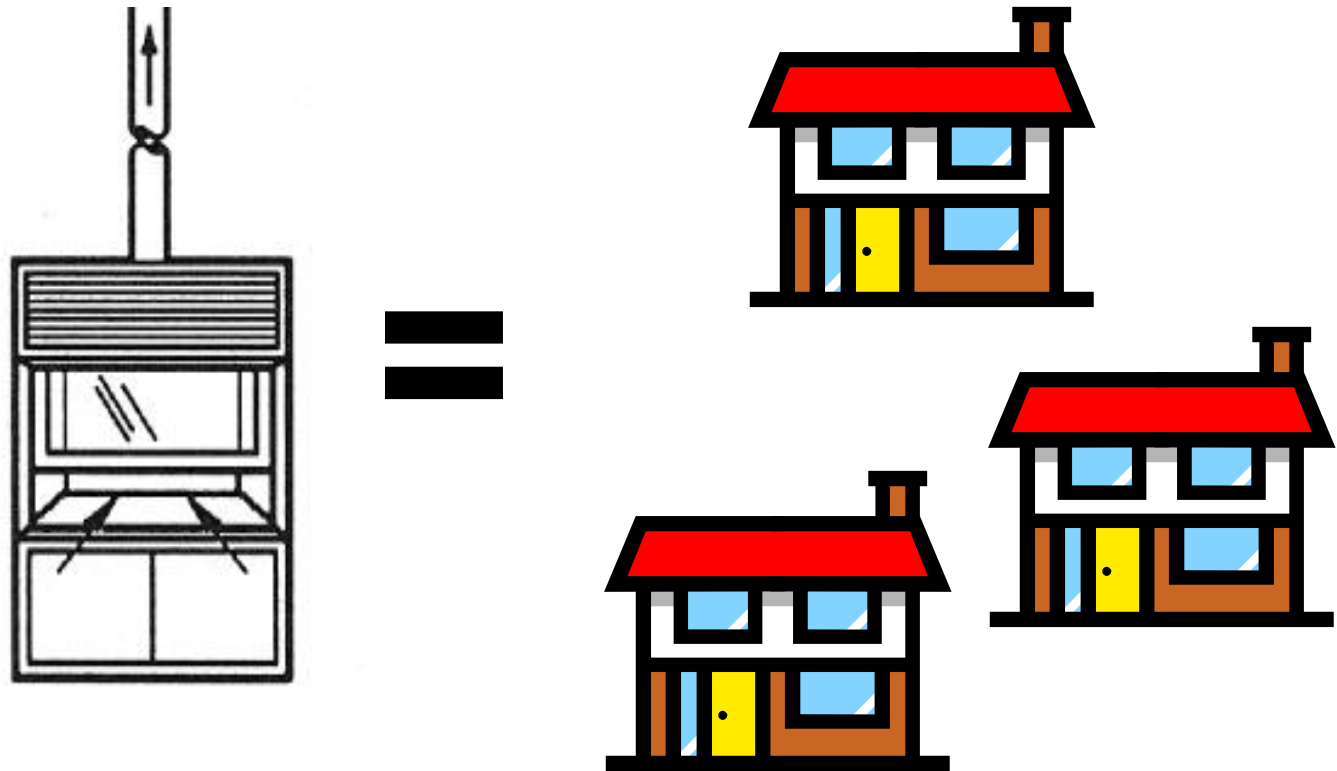
# More detail on specific best practices: Five **BIG HITS**

1. Tame the hoods
2. Scrutinize the air changes
3. Drop the pressure drop
4. Get real with plug loads
5. Just say no to re-heat



# 1. Tame the Hoods

## Fume Hood Energy Consumption





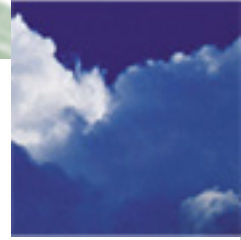
## Tame the Hoods

- Reduce number, size, and opening (restricted sash) to that required
- Design for easy removal and additions
- Use VAV or two “speed”
- Consider high performance fume hoods and better commissioning (e.g. tracer gas testing)



## 2. Scrutinize the Air Changes

- Don't assume air changes are driven by thermal loads
- What do you use as minimum ACH?
  - Why? Why? Why?
- When is ten or more air changes safe and six air changes (or less) not?
- Consider a panic switch concept
- Why is the same air change rate needed when a lab is unoccupied?
- Very large peak and operating cost impact





### 3. Drop the Pressure Drop

- Up to one half HVAC energy goes to fans
- How low can you go

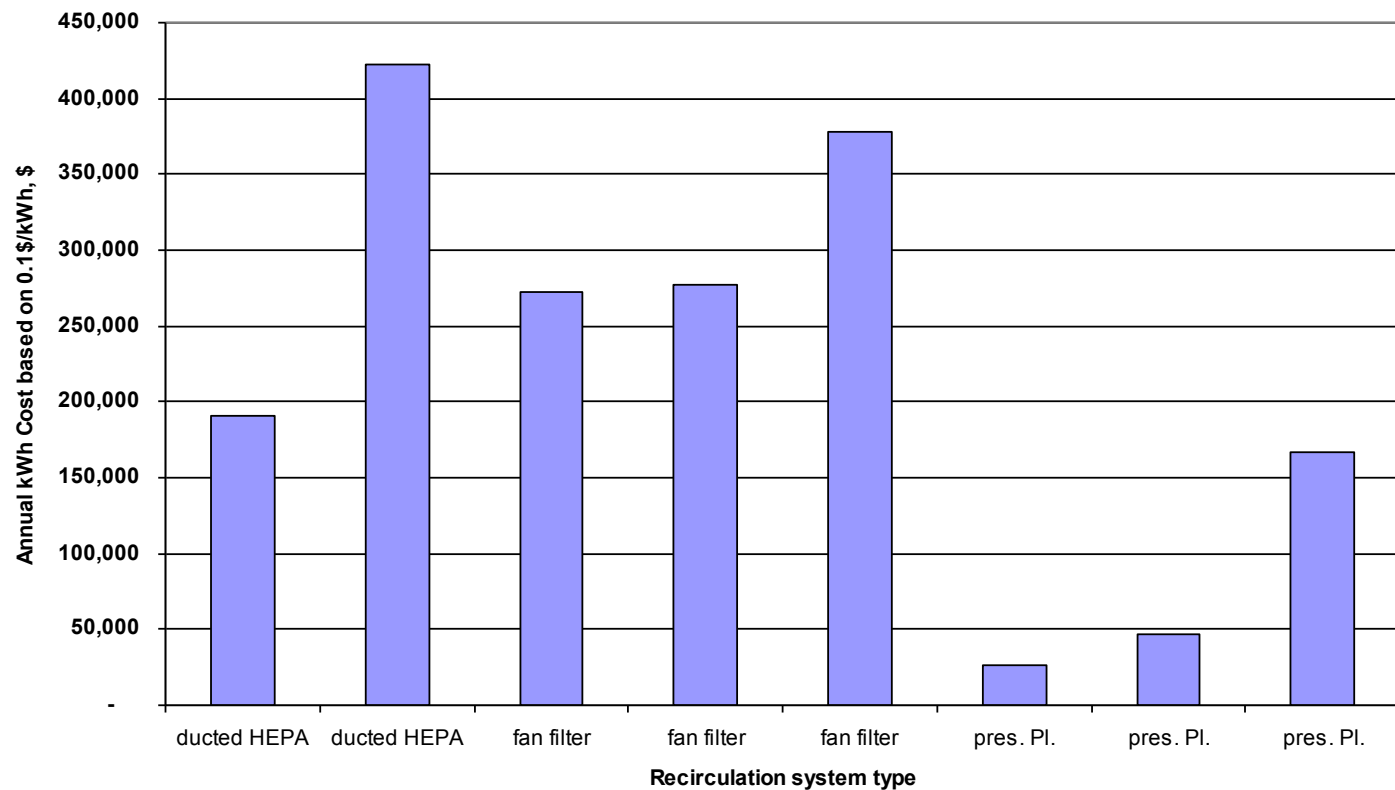
# Low Pressure-Drop Design Guidelines

| Component                           | Standard  | Good  | Better  |
|-------------------------------------|---|---|---|
| Air handler face velocity           | 500   | 400   | 300   |
| Air Handler                         | 2.5 in. w.g.  | 1.5 in. w.g.  | 0.75 in.w.g.  |
| Heat Recovery Device                | 1.00 in. w.g.   | 0.60 in. w.g.   | 0.35 in. w.g.   |
| VAV Control Devices                 | Constant Volume, N/A  | Flow Measurement Devices,<br>0.60 - 0.30 in. w.g.                                   | Pressure Differential<br>Measurement and<br>Control, 0.10 in. w.g.                  |
| Zone Temperature<br>Control Coils   | 0.5 in. w.g.  | 0.30 in. w.g.   | 0.05 in. w.g.   |
| Total Supply and Return<br>Ductwork | 4.0 in. w.g.  | 2.25 in. w.g.   | 1.2 in. w.g.  |
| Exhaust Stack CFM and               | 0.7" w.g. full design flow<br>through entire exhaust<br>system, Constant Volume | 0.7" w.g. full design flow<br>through fan and stack only,<br>VAV System with bypass | 0.75" w.g. averaging<br>half the design flow,<br>VAV System with<br>multiple stacks |
| Noise Control<br>(Silencers)        | 1.0" w.g.   | 0.25" w.g.  | 0.0" w.g.   |
| <b>Total</b>                        | <b>9.7" w.g.</b>  | <b>6.2" w.g.</b>  | <b>3.2" w.g.</b>  |
| <b>Approximate W /<br/>CFM</b>      | <b>1.8</b>  | <b>1.2</b>  | <b>0.6</b>  |

Source: J. Weale, P. Rumsey, D. Sartor, L. E. Lock, "Laboratory Low-Pressure Drop Design," ASHRAE Journal, August 2002.

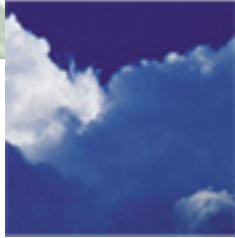
# Annual Energy Cost for Cleanroom Recirculation Fans

Annual energy costs - recirculation fans  
(Class 5, 20,000ft<sup>2</sup>)

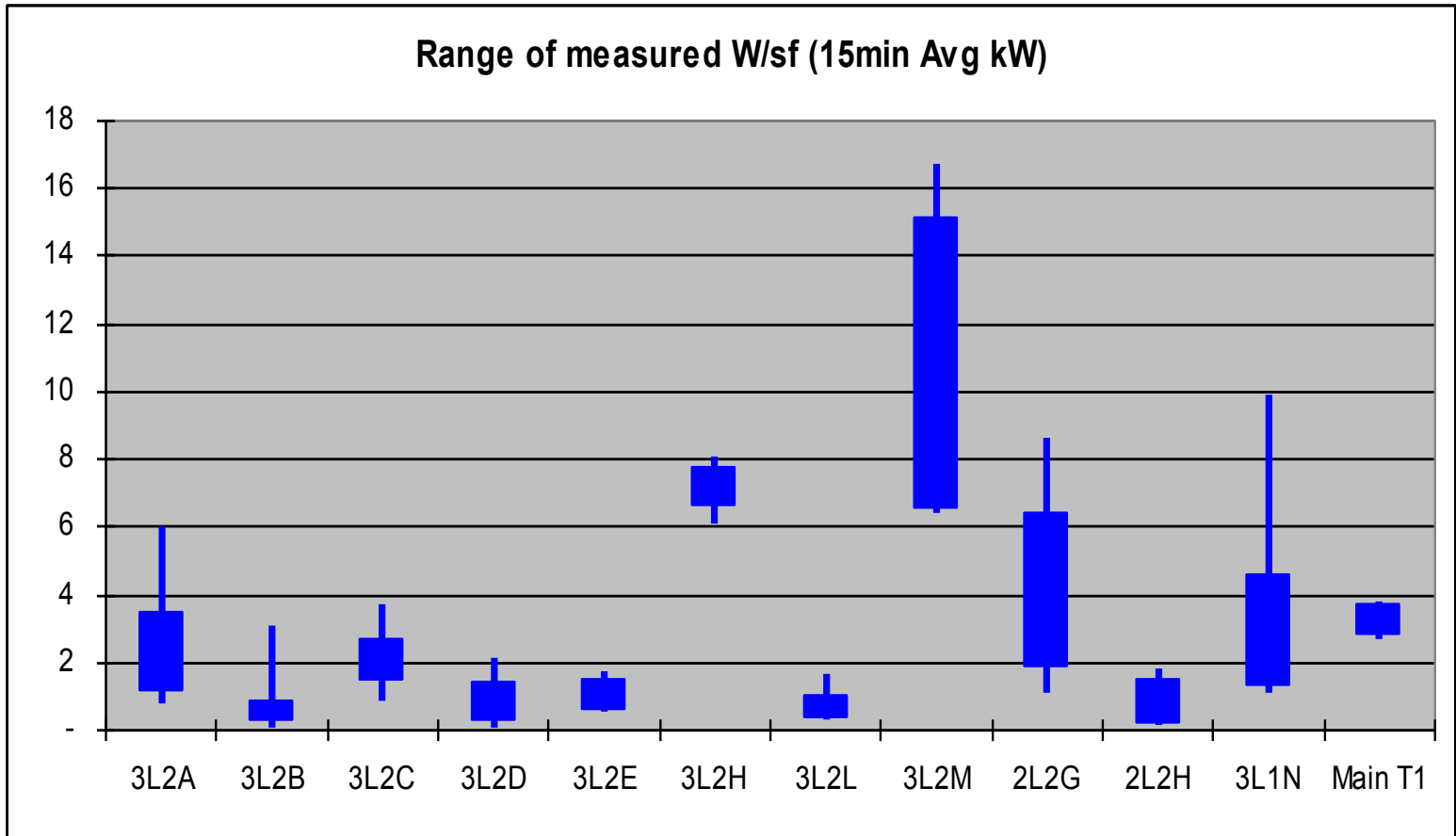


## 4. Get Real with Plug Loads

- Save capital cost and operating cost
- Measure actual loads in similar labs
- Design for high part load efficiency
  - Modular design approaches
- Plug load diversity in labs increases reheat



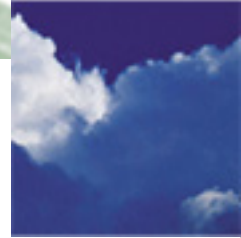
# Measured Plug Loads



**UC Davis – 16-58 W/sf design**

## 5. Just Say No to Reheat

- Reheat results in energy waste in labs
  - High-load areas require lower supply air temperature, so reheat occurs in other spaces
- Simultaneous heating and cooling can be much more problematic in a lab where the variations of internal loads can be enormous
- When reheat is employed, a single zone requiring cooling can create artificial heating and cooling loads throughout the building
- Some possible solutions are:
  - Put cooling coils or cooling fan coils in each zone.
  - Use a dual duct system with cool duct and neutral (70 deg. +/-) duct.





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